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ABSTRACT

A problem solving course designed to expose the student to the wide range of alternative problem solving techniques and to enable the student to use these methods in practical applications was developed at the University of California at Los Angeles. The course also exposes the humanities student to objective tools such as numerical models, while introducing the student of physical or life sciences to subject notions, such as values. The need for individual attention in some areas resulted in the introduction of a peer teaching program. The course material is based primarily on the book, "Patterns of Problem Solving." In a recent evaluation of the course, a majority of the students stated that the course had improved their reasoning skills, and that they had applied the tools and concepts of the course to real-life situations. Results of the use of IQ tests to assess a similar course offered at St. Louis University and taught by Steve Barlett are summarized. (SW)

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THEORETICAL AND PRACTICAL ASPECTS OF
THE UCLA PROBLEM SOLVING COURSE

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BASIC CONSIDERATIONS

The course "Patterns of Problem Solving" was developed on the UCLA campus as a result of several considerations. We felt that in a world of rapid change, education should help students acquire the abilities to restructure and transfer knowledge to new relevant situations which may arise in the future. This type of education involves the development of abilities to identify and classify problems and to identify and even restructure the skills and tools appropriate to deal with them. From both theoretical and practical considerations we did not intend to develop problem solving as a discipline unto itself, but rather as a framework for interdisciplinary cooperation. This would give students the opportunity to be exposed to different problem solving styles and approaches, thus yielding increased flexibility in the assimilation of new information. It was our hypothesis that this increase in flexibility would enhance the students' ability to more readily integrate new knowledge that initially might not appear compatible with past experiences. Increased flexibility would simply give more strength in dealing with dissonance in problem solving situations in general.

Another consideration was the theory that awareness of habits can bring about self-control of behavior. We thought that making students aware of their problem solving styles and habits would help them identify unproductive patterns, such as not canvassing alternatives, paying little attention to goal setting activity, emotional blocks, cultural constraints, etc. This awareness might help students improve their problem solving strategies and behavior in general.

An additional consideration was the hypothesis that explicit instruction in a wide variety of practical applications of heuristic and

algorithmic problem solving tools would considerably enhance the potential for using and generalizing the tools to new situations. For example, tree diagrams can be discussed in the abstract context of graph theory, but the applications can extend to problems of enumeration, classification, probability, decision making, hierarchies, outlines, organization charts, and flow charts. Such explicit emphasis on concrete applications might aid a bewildered student in seeing how to apply a tree diagram to form the skeleton structure for organizing an assigned composition.

It was also felt that bringing together in one course a heterogeneous group of students from diverse majors would provide an opportunity for exposure to different problem solving strategies. This, we hypothesized, could influence and enrich problem solving behavior.

OBJECTIVES

In identifying the primary objectives of the course we considered not only the tools, techniques, algorithms and heuristics that the problem solver might employ, but also the inner attributes and values of the problem solver. We sought a balance between techniques and human values. To maintain this balance we stipulated the following seven primary objectives of the course:

- To develop a general foundation of problem solving approaches, with mastery of some specific techniques.
- To provide a foundation for attitudes and skills productive in dealing with problems in the context of human values.
- To emphasize understanding rather than memorization and to

focus on the thinking processes at all stages of the problem solving activity.

- To identify individual problem solving styles and to learn to overcome conceptual blocks and self-imposed constraints.
- To expose students to both objective and subjective aspects of problem solving.
- To provide a framework for a better appreciation of the role of tools and concepts that the students may have acquired or will acquire.
- To bring together students from diverse backgrounds so that they can observe different attitudes and problem solving styles, and learn from each other.

Discussions and studies of possible course contents and titles resulted in the development of a course entitled "Patterns of Problem Solving," also known on the UCLA campus as Engineering 11.

The course was offered for the first time on the UCLA campus in the Fall of 1969 to a class of 32 students. By 1973, there were three sections per quarter with an enrollment of 250 students for the year. The yearly enrollment since 1976 has been about 1200 students with 12 sections of the course each quarter. The course has attracted students from more than 30 major fields and all levels at the University from freshmen to graduate students. Of approximately 3000 students in the course in 1974-1976, about 25% were from each class level and about 1/3 of the students came from the social sciences. Primary funding for the course comes from the School of Engineering, with additional funding provided by the University Office of Undergraduate Affairs.

Sections of the course have been taught by faculty members and teaching assistants from Engineering, Management, Psychology, Law, Business, Philosophy, Architecture, Urban Planning, Mathematics, and Computer Science. Teaching the course has proven to be an outstanding arena for faculty development. Most of the instructors in the course have been teaching assistants, who are normally Ph.D. candidates, and who undergo special training before teaching the course.

The course is in its tenth year on the UCLA campus and has reached a certain level of maturity in terms of objectives, content, and conduct. However, the course still retains a measure of flexibility to permit change and growth as new instructors and students from different fields continue to bring new ideas and experience.

CONTENT

The emphasis in presenting the material is on the transfer of information from the classroom to relevant practical applications. Many examples are given to illustrate the transfer of the tools and concepts to various areas of application. This emphasis is also reflected in assigned non-classroom experiences. Students are required to apply the tools they have learned to a problem of their choice. This becomes the class project and normally includes a statement of present state, goal state, alternative solutions, role of values, stipulation of constraints and uncertainties, and articulation of heuristics in the modeling and solution processes. Projects in the past have covered such diverse topics as choosing a major, selecting a career, buying a car, finding a place to live, and designing an

educational game. Although most projects are submitted in written form, some are done orally, on film, or through the use of slides.

At present, the course material is based primarily on the book, Patterns of Problem Solving, Prentice-Hall, 1975. The book consists of ten chapters. The first five chapters are devoted to general tools and concepts, such as guides to problem solving, problem representation, use of tree diagrams and flow charts, probability, language, reasoning, and modeling. The last five chapters discuss more specific topics such as decision models, cybernetic models, and models of human behavior.

The course material attempts to strike a balance between general concepts and specific techniques. But in all cases, areas of application, with emphasis on the transfer of approaches and techniques to new areas, are made as explicit as possible. This is facilitated by the heterogeneous nature of the class. A student majoring in English may demonstrate the use of a tree diagram for structuring ideas before writing a composition, poetry, or limericks. A computer science student may demonstrate for others in the class the use of trees in structured programming, with a configuration in which the level of abstraction is highest at the top and lowest at the bottom of the tree. A student of linguistics might identify yet another application of tree diagrams.

We found that through this emphasis on a number of tools with broad application, students have become more aware of the possibilities to transfer knowledge and tools from one area and its peculiar set of conditions to new areas. Thus, for example, the use of trees to structure probability problems not only improved the ability of students to solve problems in this area, but also gave them a tool they could use in structuring problems in areas as diverse as the design of a

sculpture, writing a script for a movie, or planning a career.

The first half of the course and text material are suitable for students with limited background in mathematics. The second half is a little more mathematical. The entire subject matter of the text was not intended to be taught in a ten-week quarter. The subjects taught, and the extent to which they are covered, depend on the instructor's prerogative. However, there is a core of subject matter upon which every instructor focuses. The text is not the only the source of subject material. Some topics covered during the quarter are those which an instructor introduces as a result of individual background.

While the vehicles used to teach problem solving may vary slightly from instructor to instructor, all instructors include the following aspects of problem solving in general:

- Tools for problem representation
- Models as aids to thinking
- Identifying personal problem solving styles
- Focusing on the process of problem solving
- Learning to overcome conceptual blocks
- Decision making, individual and group
- The role of values in problem solving
- The holistic and interdisciplinary nature of human problem solving.

The emphasis in the subject matter and approach is twofold; to expose the student to the wide range of alternative problem solving techniques, and to enable the student to use these methods in practical applications. The course also exposes the humanities student to

objective tools such as numerical models, while introducing the student in physical or life sciences to subjective notions, such as values.

PEER TEACHING

In 1973, a new element was added to the course by the introduction of a peer teaching program. The diverse nature of the enrollment dictated the need for individual attention in some areas. Peer teachers provided the answer to this need. This also gave the opportunity to exploit the different backgrounds of outstanding students who had completed the course, by using them as an additional learning resource. A further benefit was the more extensive feedback between instructor and student. The peer serves as a link between instructor and student-- by informing the instructor of concepts that were not conveyed well, and by clarifying parts of the lectures to the students.

In the Fall quarter of 1974, a controlled experiment was conducted to evaluate the success of the peer program. Each instructor taught two sections, with peer teachers assisting in one of them. It was found that having the peer teachers was very beneficial to the students. An unfortunate consequence was that the instructors were devoting more time to the sections with peer teachers, because they had the additional burden of training their peer teachers. This gave impetus to the creation of a peer training program which was introduced in the summer of 1974. Since that time peer teachers and teaching assistants who instruct the course go through a two-week training program each summer. This is an in-depth seminar which is also attended by a few experienced peers and instructors. The training program also affords an opportunity to get better acquainted and develop a greater sense of community.

For the last four years, the peer program has stabilized in terms of the number of peers and their duties. Generally, there are two peers per section. The peers grade homework, test and projects, and occasionally make presentations in the class. The extent of their participation in class depends upon the instructor's needs and desires. Peer teachers also put in office hours in the Peer Room, also known as the Instruction Laboratory. The peer room is centrally located between the two rooms in which the course is taught, to allow for easy and immediate access by the students, peers and instructors. The room is staffed Monday through Friday from 10:00 a.m. to 3:00 p.m., but it is usually occupied continuously by students from 9 a.m. to 5 p.m. Students are welcome in the Peer Room for any purpose, social or academic, and they have the opportunity to learn from each other in a relaxed atmosphere. The number of peers and instructors in the room at a given hour ranges from a minimum of two, to five or six at the peak hours. Usually, the room is staffed by at least one instructor each hour. The primary reason for the Peer Room is to maximize the effectiveness of the peers--it allows peers and instructors to be immediately available to help students from any section.

With the differing backgrounds of the instructors and peers, and with various sample problems, projects, and examples which instructors leave in the room, the lab has also become a small library, computer terminal, and game center.

Prospective peers are selected from Engineering 11 and Engineering 12 ("Applied Patterns of Problem Solving"--a more advanced course) with instructor recommendation. Mastery of material and general competence are a must, but another very important quality is personality. Peers

are trained not only to answer questions, but also to ask motivating questions, so that in the process the students learn to help themselves.

EVALUATION OF THE COURSE

In 1973, we conducted an experiment to establish the contribution of the course to the student's ability to formulate and solve problems. On the first day of the course the students were asked to form teams of three and to submit a solution, due at the beginning of the second week of the course, to a vaguely stated problem. The problem statement was: "Devise a plan to aid students in choosing classes at the University." Students concerned with the vagueness of the task were reminded that this was part of the problem.

When the reports were turned in, the students were told there would be one more group project later in the quarter (the project was not identified at that time). During the ensuing weeks, a graduate assistant reviewed these first papers, put comments on each of them, and compiled a list of their weaknesses. At the end of the ninth week of the quarter, the students received back their reports and were told that the second group project was to re-work the first project. In addition, each team was asked to explain how course material helped them improve their original solutions. Ten days later the re-worked projects were turned in.

The first project represented a wide range of efforts by groups with divergent interest. But three weaknesses were common to most projects. First, there was rarely a conscious attempt to define a goal state. A second deficiency was that the plans were rarely dynamic in form. Only one report contained options to be followed in case the

student changes his major, career plans, etc. In fact, the plans were usually designed with only entering Freshmen in mind. A third and most wide-spread weakness resulted from the groups' inability to define their assignments in the first place. Because of this, many plans were too narrow in scope, while others completely missed the point. In general, the papers rarely tackled the assigned problem, i.e., to design a methodology to aid students in their curriculum development.

The re-worked solutions exhibited almost uniform improvements in a number of areas. First, the groups were much better at disregarding unnecessary constraints. The plans were no longer solely career oriented nor were they strictly for entering Freshmen. The plans were dynamic, adapting to students changing their academic goals and amenable for use at any level from Freshmen to Seniors. Also, many of the solutions included some sort of feedback mechanism. A third strength was the emphasis placed on the value of added information. The re-worked plans contained a greater demand, on the part of the student to be choosing the classes, for collecting data (tests, surveys, and counselor meetings). As mentioned before, once in the midst of an academic program, added information was required for feedback analysis. A fourth improvement was the use of techniques involving utilities, and trade-offs or weighting of values, to achieve the goal state of a university education.

The greatest improvement was in the overall organization each and every project exhibited. Groups discussed goals for both their own papers, as well as for the processes they designed in the papers. Furthermore, each statement of a goal and subsequent demonstration of how the plan achieved the goal marked a giant step from the haphazardly

organized initial projects. Because of this orderly approach and the use of models, alternate representations, and problem reduction, the groups were better able to integrate the course material into their initial solutions and present greatly improved projects.

In reading the groups' critiques, it was apparent the student themselves felt the projects were most improved in the way they were organized. Each group seemed to feel that the course had given them tools to better define the problem, identify constraints, and then systematically move toward a goal state. Many reports even mentioned that course materials aided in making the group meetings more organized and more efficiently run. A majority of papers also mentioned two other areas in which the course helped them improve the final projects. First, the students felt that discussions of values and utility prepared them to deal with the subjective aspects of their problem. Also, lectures on Dynamic Systems behavior provided the groups with tools to modify their initial reports to better reflect the dynamic nature of their problem.

In addition to the above, students attributed improvement in their reports to modeling and simulation, use of computers, optimization and the guides to problem solving, such as asking the appropriate questions.

USE OF IQ TESTS TO ASSESS THE COURSE

In 1977, Steve Bartlett, Professor of Philosophy at St. Louis University, conducted an evaluation of a problem solving course he developed that was modeled after the UCLA course. He gave an IQ pre- and post-test to the students. The instrument was the California Test of Mental Maturity (CTMM), short form 1963, level 5 (mental age range

common to grade 12 - college and adult). The results he obtained were as follows (reported in a Final Report of Work Supported by the Lilly Endowment).

<u>Language IQ</u>	<u>Non-Language IQ</u>	<u>Total IQ</u>
Pre-test		
mean 126.29	120.88	127.94
range 100-138	100-137	115.142
Post-test		
mean 130.64	127.24	133-143
range 119-146	113-139	

In reporting the results, Bartlett makes the following observations:

"The above scores relate only to those students present for both the pre- and post-tests. N = 17.

In terms of total IQ, 29.4% of the students demonstrated an increase in IQ score of between 10-17 points. 52.94% of the students increased total IQ scores from 7-17 points. A total of 82.4% of the students showed some increase in their total IQ scores.

In terms of language IQ scores, 23.5% of the students demonstrated an increase of 11-19 points. 35.3% showed an increase of 8-19 points.

In terms of non-language IQ scores, 29.4% of the students demonstrated an increase of 13-24 points. 47% showed an increase of 6-24 points.

"It is empirically well-established that increases in IQ scores become progressively more difficult to produce the higher the pre-test IQ mean is. In the present case, the average initial total IQ of students in the class was 127.94. Any increase in IQ scores beyond the standard error of measurement, given this starting point, are unusual, and were not expected.

"The problem-solving class concentrated on problem-solving techniques of specific kinds--e.g., probability reasoning, use of formal representations, modeling, use of flow charts, decision methods, etc. Skills tested for on the CTMM were not emphasized. (Approximately four class meetings, only, were devoted to the types of problems encountered on the CTMM.) It seems reasonable to believe, then, that the increases detected in IQ scores indicate that general problem-solving skills possess a generalization characteristic. In other words, training in general problem-solving skills appears to improve indirectly a student's verbal comprehension, memory, and quantitative reasoning skills of the kind measured on most IQ tests.

"It should also be mentioned that the IQ post-test was given during the last week of classes, before final examinations and Christmas vacation. It is well-known that testing at such times frequently can reduce a student's raw score. In this light, the gains observed are rather more surprising.

"Improvement in general problem-solving skills was computed as follows:

$$(\text{post-test score}) - (\text{pre-test score}) = \text{improvement on a percentile scale.}$$

"This score, representing relative improvement on a 100 point scale, was then analyzed in terms of the percentage improvement of the post-test increase in relation to the pre-test score.

"This mean improvement on a percentile scale was +30 points. This corresponded to an improvement of 84.5% in relation to pre-test scores. In other words, on the average, students in the problem-solving class improved their general problem-solving skills by 84.5% in relation to their entry skills at the beginning of the semester."

CONCLUSION

Patterns of Problem Solving has had a remarkable record of success because of the course content, the preparation and training of the teaching staff, the varied opportunities for learning, the availability and helpfulness of the staff, the learning laboratory, and the enthusiasm, dedication and commitment of the instructors and peer teachers. In a recent evaluation of "Patterns of Problem Solving" conducted by the UCLA Office of Research and Evaluation, a majority of the students stated that the course has improved their reasoning skills, and that they have applied the tools and concepts of the course to real-life situations. This corroborates the findings of Bartlett in the evaluation of his course. So far, our assessments of the course at UCLA have been mostly based on testimonials from students and faculty, and on evaluation forms. This year we plan to begin an ongoing effort to generate empirical evidence of what contribution the course makes to enhance problem solving abilities. But simply on the basis of our decade of experience, we have a strong feeling that we have a good beginning in attempting to teach problem solving as an interdisciplinary course.